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FUEL CELL SYSTEM
[Nenryo denchi shisutemu]

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[Claims] /2*

[Claim 1] A fuel cell system comprising a fuel cell consisting of an electrolyte interposed between an oxidant electrode and a fuel electrode with oxidant gas supplied to the oxidant electrode side and fuel gas supplied to the fuel electrode side; an oxidant gas supplying means for supplying oxidant gas to the fuel cell via an oxidant gas supplying line; a fuel gas supplying means for supplying fuel gas to the fuel cell via a fuel gas supplying line; a fuel gas pressure control valve installed in the fuel gas supplying line to control the pressure of the fuel gas supplied to the fuel cell from the fuel gas supplying means; a circulation means for circulating the fuel gas discharged from the fuel gas discharge port of the fuel cell to the fuel gas feed port of the fuel cell via a fuel gas circulation line; a first circulation control valve installed in the fuel gas circulation line near the fuel gas discharge port of the fuel cell to control the fuel gas pressure inside the fuel cell; and a control means for controlling the fuel gas pressure control valve to supply the fuel gas from the fuel gas supplying means to the fuel cell at a predetermined pressure and for closing the first circulation control valve to charge the fuel cell with fuel gas at a predetermined charging pressure when the fuel cell is started up, afterwards extracting power generated by the fuel cell.

[Claim 2] The fuel cell system of Claim 1, wherein the control means controls the fuel gas pressure control valve to increase

* Claim and paragraph numbers correspond to those in the foreign text.

temporarily the pressure of the fuel gas supplied from the fuel gas supplying means to the fuel cell above a predetermined pressure when generated power is first extracted from the fuel cell, and wherein the control means increases the opening in the first circulation control valve after a predetermined amount of time has elapsed.

[Claim 3] The fuel cell system of Claim 2, wherein the fuel cell system further comprises a temperature-detecting means for detecting the temperature of the fuel cell, and wherein the control means sets the predetermined charging pressure, power extraction pressure, and fuel cell power extraction start timing based on the temperature of the fuel cell detected by the temperature-detecting means when the fuel cell starts up.

[Claim 4] The fuel cell system of Claim 2, wherein the control means opens the first circulation control valve and charges the fuel cell with fuel gas when the fuel cell is stopped, and then sets the power extraction pressure and fuel cell power extraction start timing based on the pressure of the fuel gas remaining inside the fuel cell when the fuel cell is started up again.

[Claim 5] The fuel cell system of Claim 1, wherein the fuel cell system further comprises a state detecting means for detecting the state of the fuel cell, a circulation flow rate calculating means for calculating the circulation flow rate inside the fuel gas circulation line based on the state of the fuel cell detected by the state detecting means, and a circulation flow rate control means for controlling the opening in the first circulation control valve in

accordance with the circulation flow rate calculated by the circulation flow rate calculating means.

[Claim 6] The fuel cell system of Claim 1, wherein the fuel cell system further comprises a second circulation control valve installed near the fuel gas feed port of the fuel cell, wherein the control means before the fuel cell is started up and after the fuel gas has been supplied at a predetermined pressure opens the first circulation valve and the second circulation valve to charge the fuel cell with fuel gas at a predetermined charging pressure and controls the fuel gas pressure control valve to supply the fuel gas at a pressure higher than the predetermined charging pressure, and wherein the control means opens the second circulation control valve when generated power is first extracted from the fuel cell, and increases the opening in the first circulation valve after a predetermined amount of time has elapsed.

[Claim 7] The fuel cell system of Claim 6, wherein the fuel cell system further comprises a temperature-detecting means for detecting the temperature of the fuel cell, and wherein the control means sets the predetermined charging pressure, the pressure higher than the predetermined charging pressure, and the control timing for the first circulation control valve and the second circulation control valve based on the temperature of the fuel cell detected by the temperature-detecting means when the fuel cell starts up.

[Claim 8] The fuel cell system of Claim 6, wherein the control means opens the first circulation control valve and the second

circulation control valve, and charges the fuel cell with fuel gas when the fuel cell is stopped, and then sets the pressure higher than the predetermined charging pressure and sets the control timing for the first circulation control valve and the second circulation control valve based on the pressure of the fuel gas remaining inside the fuel cell when the fuel cell is started up again.

[Claim 9] The fuel cell system of Claim 6, wherein the fuel cell system further comprises a release valve installed on the fuel cell discharge port side of the fuel cell for releasing fuel gas to the outside, and a purging control means for narrowing the opening in the first circulation control valve, completely opening the second circulation control valve, and then purging the fuel gas line and fuel gas circulation line inside the fuel cell with the release valve open during the purging operation.

[Detailed Description of the Invention]

[0001] [Technical Field of the Invention]

The present invention relates to a fuel cell system in which fuel gas and oxidant gas are supplied to a fuel cell to start generating electricity in the fuel cell.

[0002] [Prior Art]

So-called fuel cell stacks are used in current fuel cell systems as the power production source. These fuel cell stacks consist of fuel cell structures in which a solid polymer electrolyte is interposed between an oxidant electrode and a fuel electrode. Several of these structures are laminated on top of each other via separators. In these

fuel cell systems, hydrogen is supplied to the fuel electrode of the fuel cell stack as the fuel gas, and air containing oxygen is supplied to the air electrode. The hydrogen and oxygen react electrochemically and generate electricity directly.

[0003] In this fuel cell stack, the power generating reaction is affected by the mass transfer rate in the electrolyte and the dispersion state of the fuel gas and oxidant gas. Thus, in a fuel cell system of the prior art, the fuel gas and oxidant gas have to be supplied in quantities greater than the fuel gas and oxidant gas corresponding to the power extracted from the fuel cell stack. The fuel gas that does not contribute to the reaction is discarded.

[0004] In order to reduce the amount of fuel gas discarded, a fuel gas circulation system has been constructed for fuel cell systems of the prior art. By using an ejector pump to circulate the fuel gas discharged from the fuel cell stack back to the fuel electrode side of the fuel cell stack, the wasteful discarding of fuel gas can be reduced.

[0005] There have been various proposals for stabilizing the power output from fuel cell stacks in fuel cell systems with fuel cell circulation systems. In current fuel cell systems, the ratio of fuel gas supplied to fuel gas circulated is not controlled. Because the ratio of fuel gas supplied to fuel gas circulated is determined by using the pressure of the circulated gas only, it varies significantly depending on the operating conditions of the fuel cell stack.

[0006] For example, in Kokai No. 9-213353, a fuel gas flow rate adjusting valve is installed to adjust the flow rate of the fuel gas inside the fuel gas circulation line constituting the fuel gas circulation system. In this fuel cell system, the flow rate and pressure inside the fuel gas circulation line is adjusted based on the load in the fuel cell stack. In this way, the fuel cell system is able to operate stably.

[0007] An example of a fuel cell system of the prior art is shown in Figure 13.

[0008] This fuel cell system comprises a fuel gas supplying line L101 for supplying fuel gas to the anode (fuel electrode) of the fuel cell stack 101, a fuel gas circulation line L102 for circulating the fuel gas, an air supply line L103 for supplying air from the air supplying device 111 to the cathode (oxidant electrode) of the fuel cell stack 101, and a coolant circulating line L104 for supplying coolant to the fuel cell stack 101.

[0009] The fuel cell system is also equipped with a discharge pressure adjusting valve 112 to adjust the air pressure inside the fuel cell stack 101, and a plurality of pressure sensors 113.

[0010] In this fuel cell system, the pressure of the fuel gas accumulated in the fuel gas supplying device 121 is adjusted by the supply pressure adjusting valve 122. The fuel gas is supplied to the fuel cell stack 101 via an ejector pump 123, and the fuel gas discharged from the fuel cell stack 101 is supplied again to the fuel

cell stack 101 by the ejector pump 123 via the fuel gas circulation line L102.

[0011] In this fuel cell system, because sufficient fuel gas has accumulated in the fuel gas circulation line L102 at startup, the supply of fuel gas begins from the fuel gas supplying device 121 and the release valve 124 installed on the fuel gas discharge side of the fuel cell stack 101 is opened. In this way, the air remaining in the fuel gas circulation line L102 before startup is replaced with fuel gas. The power generation preparation stage is completed when the release valve 124 is closed.

[0012] [Problem Solved by the Invention]

Unfortunately, in a conventional fuel cell system using an ejector pump 123 on the anode side, power is extracted from the fuel cell stack 101 at startup. First, the power is extracted and the pressure is reduced in the fuel cell stack 101 by the amount of fuel gas consumed. The fuel gas then begins to flow from the fuel supply line L101 to the ejector pump 123. This causes the flow rate to decrease at the ejector nozzle. Because pressure near the ejector nozzle does not decrease sharply, sufficient pumping action cannot be obtained.

[0013] Therefore, sufficient fuel gas circulation cannot be obtained in a conventional fuel cell system at startup. In other words, the desired power output cannot be extracted stably after the fuel cell stack 101 is started up in a conventional fuel cell system.

[0014] In order to solve this problem, a release valve 124 is installed in a conventional fuel cell system to be able to release some of the fuel gas circulation line L102 to the outside at startup. In this proposed method, the fuel gas is first supplied with the release valve 124 open, the flow rate is maintained in the ejector nozzle, and power is first extracted from the fuel cell stack 101 with sufficient fuel gas circulating in the fuel gas circulation line L102. Because a sufficient flow rate is obtained in the fuel gas circulation line L102 and because the release valve 124 is closed after power extraction has been stabilized, a comparable amount of fuel gas has to be discarded.

[0015] In light of the situation described above, the present invention provides a fuel cell system able to quickly and stably obtain generated power output when the fuel cell stack is started up.

[0016] [Means for Solving the Problem]

In order to solve this problem, the invention in Claim 1 is a fuel cell system comprising a fuel cell consisting of an electrolyte interposed between an oxidant electrode and a fuel electrode with oxidant gas supplied to the oxidant electrode side and fuel gas supplied to the fuel electrode side; an oxidant gas supplying means for supplying oxidant gas to the fuel cell via an oxidant gas supplying line; a fuel gas supplying means for supplying fuel gas to the fuel cell via a fuel gas supplying line; a fuel gas pressure control valve installed in the fuel gas supplying line to control the pressure of the fuel gas supplied to the fuel cell from the fuel gas

supplying means; a circulation means for circulating the fuel gas discharged from the fuel gas discharge port of the fuel cell to the fuel gas feed port of the fuel cell via a fuel gas circulation line; a first circulation control valve installed in the fuel gas circulation line near the fuel gas discharge port of the fuel cell to control the fuel gas pressure inside the fuel cell; and a control means for controlling the fuel gas pressure control valve to supply the fuel gas from the fuel gas supplying means to the fuel cell at a predetermined pressure and for closing the first circulation control valve to charge the fuel cell with fuel gas at a predetermined charging pressure when the fuel cell is started up, afterwards extracting power generated by the fuel cell.

[0017] In the invention of Claim 2, the control means controls the fuel gas pressure control valve to increase temporarily the pressure of the fuel gas supplied from the fuel gas supplying means to the fuel cell above a predetermined pressure when generated power is first extracted from the fuel cell, and the control means increases the opening in the first circulation control valve after a predetermined amount of time has elapsed.

[0018] In the invention of Claim 3, the fuel cell system further comprises a temperature-detecting means for detecting the temperature of the fuel cell, and the control means sets the predetermined charging pressure, power extraction pressure and fuel cell power extraction start timing based on the temperature of the fuel cell

detected by the temperature-detecting means when the fuel cell starts up.

[0019] In the invention of Claim 4, the control means opens the first circulation control valve and charges the fuel cell with fuel gas when the fuel cell is stopped, and then sets the power extraction pressure and fuel cell power extraction start timing based on the pressure of the fuel gas remaining inside the fuel cell when the fuel cell is started up again.

[0020] In the invention of Claim 5, the fuel cell system further comprises a state detecting means for detecting the state of the fuel cell, a circulation flow rate calculating means for calculating the circulation flow rate inside the fuel gas circulation line based on the state of the fuel cell detected by the state detecting means, and a circulation flow rate control means for controlling the opening in the first circulation control valve in accordance with the circulation flow rate calculated by the circulation flow rate calculating means.

[0021] In the invention of Claim 6, the fuel cell system further comprises a second circulation control valve installed near the fuel gas feed port of the fuel cell, the control means before the fuel cell is started up and after the fuel gas has been supplied at a predetermined pressure opens the first circulation valve and the second circulation valve to charge the fuel cell with fuel gas at a predetermined charging pressure and controls the fuel gas pressure control valve to supply the fuel gas at a pressure higher than the predetermined charging pressure, and the control means opens the

second circulation control valve when generated power is first extracted from the fuel cell, and increases the opening in the first circulation valve after a predetermined amount of time has elapsed.

[0022] In the invention of Claim 7, the fuel cell system further comprises a temperature-detecting means for detecting the temperature of the fuel cell, and the control means sets the predetermined charging pressure, the pressure higher than the predetermined charging pressure, and the control timing for the first circulation control valve and the second circulation control valve based on the temperature of the fuel cell detected by the temperature-detecting means when the fuel cell starts up.

[0023] In the invention of Claim 8, the control means opens the first circulation control valve and the second circulation control valve, and charges the fuel cell with fuel gas when the fuel cell is stopped, and then sets the pressure higher than the predetermined charging pressure and sets the control timing for the first circulation control valve and the second circulation control valve based on the pressure of the fuel gas remaining inside the fuel cell when the fuel cell is started up again.

[0024] In the invention of Claim 9, the fuel cell system further comprises a release valve installed on the fuel cell discharge port side of the fuel cell for releasing fuel gas to the outside, and a purging control means for narrowing the opening in the first circulation control valve, completely opening the second circulation control valve, and then purging the fuel gas line and fuel gas

circulation line inside the fuel cell with the release valve open during the purging operation.

[0025] [Effect of the Invention]

In the invention of Claim 1, when the fuel cell is started up, fuel gas is supplied to the fuel cell at a predetermined pressure, the first circulation control valve is closed to charge the fuel cell with fuel gas at the predetermined charging pressure, and the power generated by the fuel cell is then extracted. Because the fuel gas at the fuel cell intake port and in circulation line is charged at a high preset pressure, the fuel gas flows in at once on the fuel cell intake side as soon as power generation is started. As a result, sufficient fuel gas is supplied for the output. This also prevents a sharp reduction in the output voltage of the fuel cell due to insufficient fuel gas in the fuel cell immediately after the generated power is extracted.

[0026] In other words, the fuel cell system in Claim 1 increases the flow rate of the fuel gas supplied to the fuel cell at the start of power extraction, sufficiently manifests the effects of a circulating means, and obtains power output quickly and stably.

[0027] In the invention of Claim 2, the pressure of the fuel gas supplied to the fuel cell is temporarily increased above a predetermined pressure when the extraction of generated power from the fuel cell is started. The opening in the first circulation control valve is also increased after a predetermined amount of time. This prevents a back glow of fuel gas from the fuel gas circulation line to

the fuel gas discharge port of the fuel cell when the first circulation control valve is opened, and more adequately manifests the effects of a circulation means.

[0028] In the invention of Claim 3, the predetermined charging pressure, power extraction pressure and fuel cell power extraction start timing are set based on the detected temperature of the fuel cell when the fuel cell starts up. As a result, the optimum power output can be stably obtained at startup based on the temperature conditions of the fuel cell regardless of the heater or cooler of the fuel cell.

[0029] In the invention of Claim 4, the first circulation control valve is opened and the fuel cell is charged with fuel gas when the fuel cell is stopped, and then the power extraction pressure and fuel cell power extraction start timing are set based on the pressure of the fuel gas remaining inside the fuel cell when the fuel cell is started up again. As a result, a purge operation is not required to replace the gas inside the lines when the system is restarted. This reduces the amount of time needed to restart the system.

[0030] In the invention of Claim 5, the circulation flow rate inside the fuel gas circulation line is calculated based on the state of the fuel cell, and the opening in the first circulation control valve is controlled in accordance with the calculated circulation flow rate. Because the circulation flow rate is controlled properly by the first circulation control valve, optimum operating conditions can be realized for the fuel cell.

[0031] In the invention of Claim 6, before the fuel cell is started up and after the fuel gas has been supplied at a predetermined pressure the first circulation valve and the second circulation valve are opened to charge the fuel cell with fuel gas at a predetermined charging pressure and the fuel gas pressure control valve is controlled to supply the fuel gas at a pressure higher than the predetermined charging pressure, the second circulation control valve is opened when generated power is first extracted from the fuel cell, and the opening in the first circulation valve is increased after a predetermined amount of time has elapsed. As a result, fuel gas can be supplied at a high flow rate to the fuel cell downstream from the first circulation control valve when generated power is first extracted. The generated power can also be more quickly stabilized at startup.

[0032] In the invention of Claim 7, the predetermined charging pressure, the pressure higher than the predetermined charging pressure, and the control timing for the first circulation control valve and the second circulation control valve are set based on the temperature of the fuel cell detected by the temperature-detecting means when the fuel cell starts up. As a result, the optimum power output can be stably obtained at startup based on the temperature conditions of the fuel cell regardless of the heater or cooler of the fuel cell, and the generated power can be extracted quickly and stably.

[0033] In the invention of Claim 8, the first circulation control valve and the second circulation control valve are opened, and the fuel cell is charged with fuel gas when the fuel cell is stopped, and the pressure higher than the predetermined charging pressure and the control timing for the first circulation control valve and the second circulation control valve are set based on the pressure of the fuel gas remaining inside the fuel cell when the fuel cell is started up again. As a result, the generated power can be extracted more quickly and stably even after extraction of power from the fuel cell has been stopped.

[0034] In the invention of Claim 9, the opening in the first circulation control valve is narrowed, the second circulation control valve is completely opened, and then the fuel gas line and fuel gas circulation line inside the fuel cell are purged with the release valve open during the purging operation. When the release valve is opened during purging, reverse flow from the circulation line directly to the release valve can be prevented. The circulation flow rate after purging can be quickly stabilized, the supplied gas flow rate can be increased, and the nitrogen and condensed water accumulated in the circulation lines can be readily discharged.

[0035] [Embodiment of the Invention]

The following is an explanation of an embodiment of the present invention with reference to the figures.

[0036] Figure 1 is a block diagram of the first configuration example of the fuel cell system of the present invention.

[0037] [First Configuration Example Of Fuel Cell System]

As shown in Figure 1, the fuel cell system comprises a fuel gas supplying line L1 for supplying fuel gas to the anode 1a of the fuel cell stack 1, a fuel gas circulating line L2 for circulating the fuel gas discharged from the anode 1a of the fuel cell stack 1, an oxidant gas supplying line L3 for supplying the oxidant gas to the cathode 1b of the fuel cell stack 1, an oxidant gas discharging line L4 for discharging the oxidant gas discharged from the cathode 1b, and a coolant circulating line L5 for circulating the coolant inside the fuel cell stack 1.

[0038] This fuel cell system is also equipped with a control unit 21 for controlling the overall system. This control unit 21 performs controls, such as starting and stopping operation of the fuel cell stack 1, by outputting control signals to the various components described below.

[0039] A fuel gas supplying device 2 for storing fuel gas, a supply pressure control valve 3, and an ejector pump 4 are arranged in the fuel gas supplying line L1. The supply pressure control valve 3 is equipped with a first actuator 5 for adjusting the opening in the supply pressure control valve 3, a first pressure sensor 6 installed between the supply pressure control valve 3 and the ejector pump 4, and a second pressure sensor 7 installed between the ejector pump 4 and the fuel cell stack 1.

[0040] When power is generated by the fuel cell stack 1 in this fuel cell system, the sensor signals detected by the first pressure

sensor 6 and the second pressure sensor 7 are monitored by the control unit 21. The first actuator 5 is controlled by the control unit 21 to adjust the opening in the supply pressure control valve 3, and fuel gas is supplied to the anode 1a of the fuel cell stack 1 via the ejector pump 4.

[0041] In the fuel gas circulation line L2 are installed a circulation control valve 8 located near the fuel gas discharge port of the fuel cell stack 1, a second actuator 9 for adjusting the opening in the circulation control valve 8, a third pressure sensor 10 interposed between the fuel cell stack 1 and the circulation control valve 8, and a fourth pressure sensor 11 interposed between the circulation control valve 8 and the ejector pump 4.

[0042] When electricity is being generated in the fuel cell stack 1 of this fuel cell system, the control unit 21 monitors the sensor signals detected by the first pressure sensor 6 and the second pressure sensor 7. The control unit 21 then controls the first actuator 5 to adjust the opening in the supply pressure control valve 3. This controls the pressure of the fuel gas supplied to the fuel cell stack 1. The control valve 21 then monitors the sensor signals detected by the first pressure sensor 6, the second pressure sensor 7, the third pressure sensor 10 and the fourth pressure sensor 11, and the control unit 21 controls the second actuator 9 to adjust the opening in the circulation control valve 8. This provides the optimum fuel gas flow rate to the fuel cell stack 1.

[0043] The oxidant gas supplying line L3 is equipped with an air supplying device 12 for supplying air from the outside to the fuel cell stack 1 as the oxidant gas.

[0044] When the fuel cell stack 1 is generating electricity, the air supplying device 12 controls the drive rate based on control signals from the control unit 21. This controls the amount of oxidant gas taken in from the outside and supplies the oxidant gas to the oxidant gas supplying line L3.

[0045] The oxidant gas discharging line L4 is equipped with a discharge pressure control valve 13 on the oxidant gas discharge end of the fuel cell stack 1 and a third actuator 14 for adjusting the opening in the discharge pressure control valve 13.

[0046] When the fuel cell stack 1 in this fuel cell system is generating power, control signals for adjusting the opening in the discharge pressure control valve 13 are outputted to the third actuator 14 to adjust the pressure of the oxidant gas supplied to the fuel cell stack 1.

[0047] A coolant circulating device (not shown) is connected to the coolant circulating line L5. When the fuel cell stack 1 is in operation, the flow rate of the coolant is adjusted to keep the fuel cell stack 1 at a predetermined temperature.

[0048] The fuel cell system is also equipped with a release valve 15 to release the fuel gas discharged from the anode 1a in the fuel cell stack 1 to the outside and a fourth actuator 16 for adjusting the opening in the release valve 15. The control unit 21 supplies control

signals to open the release valve 15 to the fourth actuator 16 when the purging operation is performed to discharge the moisture and nitrogen in the fuel cell stack 1 and the fuel gas circulating line L2 to the outside.

[0049] The control unit 21 inputs sensor signals from the various pressure sensors described above and controls the generation of electricity in the fuel cell stack 1 based on the sensor signals by performing the various processes described below. The following is a detailed explanation of the processes performed by the control unit 21.

[0050] Startup Control Process for Fuel Cell System in First Configuration Example

Figure 2 is flowchart showing the processing steps performed by the control unit 21 when the startup control process is performed.

[0051] The control unit 21 begins the startup control process below in Step S1 in response to an outside command to start generating power in the fuel cell stack 1.

[0052] In Step S1, the control unit 21 controls the fourth actuator 16 to open the release valve 15 and controls the second actuator 9 to open the circulation control valve 8.

[0053] Next, in Step S2, the control unit 21 controls the fuel gas supplying device 2 and the supply pressure control valve 3 to supply fuel gas to the fuel cell stack 1, and controls the air supplying device 12 to supply oxidant gas to the fuel cell stack 1. In this fuel cell system, a purging operation is performed before

starting up the fuel cell stack 1 to release the residual gas remaining inside the fuel gas supplying line L1 and the fuel gas circulating line L2 to the outside.

[0054] Next, in Step S3, the control unit 21 activates an internal timer (not shown) and determines whether or not a predetermined amount of time has elapsed since the start of fuel gas and oxidant gas supply in Step S2. This predetermined amount of time is the time required to purge the residual gas inside the fuel cell stack 1 and the fuel gas circulating line L2 with fuel gas.

[0055] When the predetermined amount of time has not elapsed, the control unit 21 continues to supply fuel gas and oxidant gas. When the predetermined amount of time has elapsed, the control unit 21 has discharged the residual gas in the fuel cell stack 1 and the fuel gas circulating line L2 and replaced it with fuel gas. The process then advances to Step S4.

[0056] In Step S4, the control unit 21 controls the fuel gas supplying device 2, the supply pressure control valve 3 and the air supplying device 12 to stop the supply of fuel gas and oxidant gas to the fuel cell stack 1. It also controls the second actuator 9 and the fourth actuator 16 to close the circulation control valve 8 and the release valve 15.

[0057] Next, in Step S5, the control unit 21 controls the supply pressure control valve 3 to supply fuel gas to the fuel cell stack 1 so as to maintain a predetermined charging pressure inside the fuel cell stack 1. The discharge pressure control valve 13 is also

controlled to begin supplying oxidant gas to the fuel cell stack 1 at the same pressure as the predetermined charging pressure mentioned above.

[0058] Because the circulation control valve 8 and the release valve 15 are closed in Step S4, the fuel gas is charged in a channel consisting of the fuel gas supplying line L1, the fuel cell stack 1 and the release valve 15 and in a channel consisting of the fuel cell stack 1 and the circulation control valve 8.

[0059] Next, in Step S6, the control unit 21 starts the supply in Step S5 and determines whether or not the pressure inside the fuel cell stack 1 has reached the predetermined charging pressure based on the sensor signals from the third pressure sensor 10. When the control unit 21 has determined that the pressure inside the fuel cell stack 1 has reached the predetermined charging pressure, the process advances to Step S7. If the predetermined charging pressure has not been reached, the supply of fuel gas to the fuel cell stack 1 is continued.

[0060] In Step S7, the control unit 21 activates the internal timer to maintain the predetermined charging pressure reached in Step S6 for a predetermined time only.

[0061] Next, in Step S8, the control unit 21 starts the extraction of power generated by the fuel cell stack 1. Here, the control unit 21 controls the supply of power generated by the fuel cell stack 1 to a battery or load (not shown).

[0062] Next, in Step S9, the control unit 21 controls the first actuator 5 to open the supply pressure control valve 3 a certain degree to set the power extraction pressure for the fuel gas. At the same time, it controls the air supplying device 12 and the discharge pressure control valve 13 to control the oxidant gas supply pressure based on the change in fuel gas supply pressure to the fuel cell stack 1.

[0063] Next, in Step S10, the control unit 21 incorporates the sensor signals from the voltage sensor (not shown) connected to the fuel cell stack 1, and determines whether or not the output voltage value incorporated from the fuel cell stack 1 is lower than the pre-set warning lower limit voltage. Here, the warning lower limit voltage is the lower limit value for the output voltage determined based on the power generating reaction of the fuel cell stack 1 when fuel gas and oxidant gas are being supplied.

[0064] When the output voltage is lower than the warning lower limit voltage, the control unit 21 determines that the power generating reaction is not being performed normally in the fuel cell stack 1 and the process advances to Step S11. If the output voltage is not lower than the warning lower limit voltage, the control unit 21 determines that the power generating reaction is being performed normally in the fuel cell stack 1 and the process advances to Step S12.

[0065] In Step S11, the control unit 21 determines that the power generating reaction is not being performed normally in the fuel cell

stack 1, stops the extraction of power from the fuel cell stack 1, and the process advances to Step S1.

[0066] In Step S12, the control unit 21 determines whether or not a predetermined amount of time has elapsed since power was first drawn from the fuel cell stack 1 in Step S8. If the control unit 21 determines that the predetermined amount of time has elapsed, the process advances to Step S13. If it determines that the predetermined amount of time has not elapsed, the process advances to Step S10. If the output voltage value is greater than the warning lower limit voltage at the point in time at which the predetermined amount of time has elapsed since power was first drawn from the fuel cell stack 1 in Step S8, the control unit 21 advances to Step S13.

[0067] In Step S13, the control unit 21 controls the second actuator 9 to open the circulation control valve 8.

[0068] Next, in Step S14, the control unit 21 as in Step S10 determines after the circulation control valve 8 has been opened whether or not the output voltage value from the fuel cell stack 1 is less than the predetermined warning lower limit voltage. If it is less, the process returns to Step S11. If not less, the process advances to Step S15 and the fuel cell stack 1 continues normal operations.

[0069] In a fuel cell system performing this process, as shown in Figure 3, the fuel gas is charged at a predetermined charging pressure with the supply voltage control valve 3 open in Step S5. When power is first extracted from the fuel cell stack 1 at time t1 (Step S8), the

amount of fuel gas in circulation is increased (b). This keeps the output voltage from falling sharply immediately after time t1.

[0070] In this way, the fuel cell system can increase the fuel gas flow rate at the ejector nozzle where the fuel gas is released into the fuel cell stack 1 from the ejector pump 4 at the start of power extraction. This realizes sufficient pumping effect by the ejector pump 4 and quickly stabilizes power generation at the startup of the fuel cell stack 1.

[0071] When the fuel gas has not been charged beforehand using the circulation control valve 8, as indicated by the comparative example in Figure 3, and power is first extracted from the fuel cell stack, the fuel gas is consumed in the fuel cell stack 1, the generated pressure declines, fuel gas flows in from both the fuel gas intake and discharge ports, reverse flow occurs in the fuel gas circulation line, sufficient circulation flow cannot be obtained, and a sufficient supply of fuel gas cannot be obtained (b). As a result, the output voltage decreases sharply immediately after power generation starts (a).

[0072] In a fuel cell system performing the startup control process described above, the circulation control valve 8 is opened in Step S13 after a predetermined amount of time has elapsed since power was first extracted in Step S8. Because there is a predetermined time difference between the power extraction start time and the circulation valve 8 opening time, reverse flow into the fuel gas intake port is prevented at generation startup and circulator flow occurs in the

proper direction immediately after generation startup. This ensures a sufficient flow of fuel gas and helps prevent a decline in outputted voltage.

[0073] Also, in this fuel cell system, the circulation flow rate does not have to be ensured by starting power generation after the purging operation. As a result, fuel gas is not consumed wastefully.

[0074] [Startup Control Setting Process]

The preceding was an explanation of a process for presetting in the fuel cell system the extractable power from the fuel cell stack 1, the predetermined charging pressure used as a reference in Step S6, the fuel gas pressure supplied by the supply pressure control valve 3 when power extraction is started in Step S9, and the predetermined period of time determined in Step S12. The startup control setting process shown in Figure 4 should be performed before Step S1 in Figure 2.

[0075] The control unit 21 begins the startup control setting process in Step S21 based on a command from the outside to start power generation in the fuel cell stack 1.

[0076] As shown in Figure 4, first, in Step S21, the control unit 21 inputs sensor signals from the temperature sensor (not shown) used to detect the temperature in the fuel cell stack 1 in order to obtain the temperature of the fuel cell stack 1.

[0077] Next, in Step S22, the control unit 21 references the output correction map shown in Figure 5 based on the temperature of

the fuel cell stack 1 obtained in Step S21, and calculates the power output value extractable from the fuel cell stack 1.

[0078] In the output correction map shown in Figure 5, the horizontal axis denotes the load ratio [%] indicating the voltage value with respect to the maximum power output extractable from the fuel cell stack 1, and the vertical axis denotes the power output value extractable from the fuel cell stack 1 based on the temperature. The control unit 21 stores power output values extractable at the load ratio as a table in the internal memory. These values change based on the temperature of the fuel cell stack 1 and the fuel gas pressure. In Step S22, the control unit 21 calculates the power output value extractable at the load ratio based on the temperature of the fuel cell stack 1 detected in Step S21.

[0079] Next, in Step S23, the control unit 21 calculates based on the extractable power output obtained in Step S22 the predetermined charging pressure used as a reference in Step S6, the pressure of the fuel gas supplied during power extraction from the supply pressure control valve 3 at power extraction startup in Step S9, and the predetermined period of time determined in Step S12 from the line capacity of the fuel gas circulation line L2 and the performance of the ejector pump 4, and the process is started from Step S1 in Figure 2. By calculating the time period determined in Step S12, the control unit 21 can determine the drive time for the circulation control valve 8 in Step S13.

[0080] In a fuel cell system performing this startup control setting process, the power output extractable at startup is calculated based on the temperature of the fuel cell stack 1 at startup, and the predetermined charging pressure in Step S6, the fuel gas pressure at power extraction supplied in Step S9, and the drive timing of the circulation control valve 8 in Step S13 are changed based on the extractable power output.

[0081] In this way, the fuel cell system can stably extract the optimum power output based on the temperature conditions of the fuel cell stack 1 at startup regardless of the heater or cooler of the fuel cell.

[0082] [System Restart Control Process]

Figure 6 is a flowchart of processing steps performed by the control unit 21 in the fuel cell system shown in Figure 1, when the system restart control process is performed.

[0083] In Step S11 shown in Figure 2, the control unit 21 starts the system restart control process from Step S31 in response to output from the fuel cell stack 1 stopping.

[0084] In Step S31, the control unit 21 controls the supply pressure control valve 3, the circulation control valve 8 and the release valve 15 to charge the fuel gas at the predetermined pressure, and controls the air supplying device 12 and the discharge pressure control device 13 to charge the fuel cell stack 1 with oxidant gas at the same predetermined pressure as the fuel gas.

[0085] Next, in Step S32, the control unit 21 determines whether or not a request has been received in the form of an external command to draw power from the fuel cell stack 1. If an output request has been received, the control unit 21 advances to Step S33. Fuel gas and oxidant gas are supplied based on the requested power output, and the normal power extraction operation is performed. If an output request has not been received, the control unit 21 the process advances to Step 34.

[0086] In Step S34, the control unit 21 determines whether or not the ignition switch (IGN) controlled by the operator is turned off. If the ignition switch is not turned off, the control unit 21 returns to the process in Step S32. If the ignition switch is turned off, the process advances to Step S35 and the entire fuel cell system is turned off.

[0087] Next, in Step S36, the control unit 21 begins to restart the fuel cell system. In Step S37, sensor signals from the temperature sensor (not shown) used to detect the temperature of the fuel cell stack 1 are inputted and the temperature is identified. The input of sensor signals from the third pressure sensor 10 are then used to detect the residual charging pressure of the remaining fuel gas inside the fuel cell stack 1.

[0088] Next, in Step S38, the control unit 21 reads the output versus pressure map stored in the memory showing the relationship between the power output extractable from the fuel cell stack 1 and the residual charging pressure. In this way, the control unit 21

identifies the power output for the residual charging pressure detected in Step S37. Next, the control unit 21 corrects the identified power output based on the temperature detected in Step S37.

[0089] The control unit 21 performing this system restart control process can determine the power output extracted in the next Step S8 based on the residual charging pressure and the temperature, even when power extraction from the fuel cell stack 1 has been stopped in Step S11.

[0090] Thus, by performing the process in Step S31 when the system is shut down, the fuel cell system can calculate the extractable power based on the residual charging pressure if the fuel gas is charged normally at the predetermined pressure, and change the fuel gas pressure supplied in Step S9 and the drive timing for the circulation control valve 8 in Step S13 in response to the calculated power output.

[0091] In this fuel cell system, the fuel cell stack 1 is charged in Step S31 at a predetermined pressure with fuel gas and oxidant gas even after output from the fuel cell stack 1 has been stopped. This makes a purge operation performed with the release valve 15 as in Step S2 unnecessary when the system is started back up, and the process can start directly with Step S8. Thus, this fuel cell system requires less time for system startup.

[0092] [Circulation Flow Rate Control Process During Normal Operation]

Figure 7 is a flowchart showing the processing steps performed by the control unit 21 when the circulation flow rate control process is performed during normal operations other than startup operations.

[0093] The control unit 21 performs the process starting at Step S41 after Step S15 in Figure 2 described above.

[0094] In Step S41, the control unit 21 detects the current state of the fuel cell stack 1, and calculates the optimum fuel gas flow rate for the fuel gas circulation line L2. Here, the control unit 21 detects the state of the fuel cell stack 1 using the temperature sensor and voltage sensor (not shown), and calculates the fuel gas flow rate needed for the detected state of the fuel cell stack 1. In this way the optimum circulation flow rate is calculated for the fuel gas circulation line L2.

[0095] Next, in Step S42, the control unit 21 determines whether the circulation flow rate for the fuel gas circulation line L2 calculated in Step S41 is optimum. Here, the control unit 21 detects the circulation flow rate in the fuel gas circulation line L2 using a flow rate detecting means such as a flow rate sensor in the fuel gas circulation line L2. If the control unit 21 determines that the current circulation flow rate in the fuel gas circulation line L2 is optimum, the process returns to Step S41. If the control unit determines that the current circulation flow rate in the fuel gas circulation line L2 is not optimum, the process advances to Step S43.

[0096] In Step S43, the control unit 21 determines whether or not the current circulation flow rate detected in Step S42 is greater than

the optimum circulation flow rate calculated in Step S41. If the control unit 21 determines that the current circulation flow rate is greater than the optimum circulation flow rate, the process advances to Step S44. If it determines that the current circulation flow rate is not greater than the optimum circulation flow rate, the process advances to Step S46.

[0097] In Step S44, the control unit controls the second actuator 9 to narrow the opening in the circulation control valve 8 and lower the current circulation flow rate in the fuel gas circulation line L2.

[0098] Next, in Step S45, the control unit determines whether or not a command has been inputted from the outside to stop the fuel cell stack 1 and, thus, whether or not power extraction from the fuel cell stack 1 is to be stopped. If the control unit 21 determines that power extraction from the fuel cell stack 1 is to be stopped, the process ends. If it determines that power extraction from the fuel cell stack 1 is not to be stopped, the process returns to Step S41.

[0099] If it is determined in Step S46 that the current circulation flow rate from Step S43 is not greater than the optimum circulation flow rate, the control unit 21 controls the second actuator 9 to increase the opening in the circulation control valve 8 and increase the current circulation flow rate in the fuel gas circulation line L2.

[0100] Next, in Step S47, the control unit 21 determines whether a command has been inputted from the outside to stop the fuel cell stack 1 or whether or not to stop extracting power from the fuel cell

stack 1. If the control unit 21 determines that power extraction from the fuel cell stack 1 is to be stopped, the process ends. If it determines that power extraction from the fuel cell stack 1 is not to be stopped, the process returns to Step S41.

[0101] If this fuel cell system has an adjustable circulation control valve 8, the opening in the circulation control valve 8 is adjusted during normal operation in addition to startup to adjust the circulation flow rate and circulation pressure in the fuel gas circulation line L2. This controls the utilization rate of fuel gas based on the current state such as the load and temperature of the fuel cell stack 1.

[0102] [Another Configuration of the Fuel Cell System]

The following is an explanation of the fuel cell system in a second configuration example of the present invention. In the following example, an explanation of the components identical to those in the first configuration example of the fuel cell system has been omitted.

[0103] The second configuration example of the fuel cell system is shown in Figure 8. In this fuel cell system, between the ejector pump 4, the second pressure sensor 7 and the fuel cell stack 1 are installed a second circulation control valve 31 near the fuel gas feed port of the fuel cell stack 1, a fifth pressure sensor 32 for detecting the fuel gas pressure in a pipe connecting the second circulation control valve 31 and the fuel cell stack 1, and a fifth actuator 33 for controlling the opening in the second circulation

control valve 31. Otherwise, the configuration is identical to the fuel cell system in Figure 1. In the following explanation, the circulation control valve 8 described above is called the first circulation control valve 8.

[0104] [Startup Control Process in the Second Configuration Example of the Fuel Cell System]

Figure 9 is flowchart showing the processing steps performed by the control unit 21 in the fuel cell system shown in Figure 8 when the start control process is performed.

[0105] The control unit 21 begins the startup control process at Step S51 based on a command from the outside to start generating power in the fuel cell stack 1.

[0106] In Step S51, the control unit 21 controls the fourth actuator 16 to open the release valve 15, and controls the fifth actuator 33 and the second actuator 9 to open the second circulation control valve 31 and the first circulation control valve 8.

[0107] Next, in Step S52, the control unit controls the fuel gas supplying device 2 and the supply pressure control valve 3 to supply fuel gas to the fuel cell stack 1, and controls the air supplying device 12 to supply oxidant gas to the fuel cell stack 1. In this way, the fuel cell system purges the fuel cell stack 1 and the fuel gas circulating line L2 of residual gas before startup.

[0108] Next, in Step S53, the control unit 21 activates the internal timer (not shown) and determines whether a predetermined amount of time has elapsed since the start of the supply of fuel gas

and oxidant gas in Step S52. When the control unit 21 determines that the predetermined amount of time has elapsed, the residual gas in the fuel cell stack 1 and the fuel gas circulating line L2 is discharged and replaced with fuel gas. The process then advances to Step S54.

[0109] In Step S54, the control unit 21 controls the fuel gas supplying device 2, the supply pressure control valve 3, and the air supplying device 12 to stop the supply of fuel gas and oxidant gas to the fuel cell stack 1. It also controls the second actuator 9 and the fourth actuator 16 to close the first circulation control valve 8 and the release valve 15.

[0110] In Step S55, the control unit 21 controls the supply pressure control valve 3 to supply fuel gas to the fuel cell stack 1 in such a way as to obtain the predetermined charging pressure inside the fuel cell stack 1. It also controls the discharge pressure control valve 13 to begin supplying oxidant gas to the fuel cell stack 1 at the same pressure as the predetermined pressure.

[0111] Because the first circulation control valve 8 and the release valve 15 are closed in Step S54, the fuel gas charges a line consisting of the fuel gas supplying line L1, the fuel cell stack 1 and the release valve 15, and a line consisting of the fuel cell stack 1 and the first circulation control valve 8.

[0112] Next, in Step S56, the control unit 21 starts the supply in Step S55 based on sensor signals from the fifth pressure sensor 32, and determines whether or not the pressure inside the fuel cell stack 1 has reached the predetermined charging pressure. When the control

unit 21 determines that the pressure inside the fuel cell stack 1 has reached the predetermined charging pressure, the process advances to Step S57.

[0113] In Step S57, the control unit 21 controls the fifth actuator 33 to close the second circulation control valve 31, controls the first actuator 5 using the supply pressure control valve 3 so that the pressure is greater than the predetermined charging pressure, and supplies fuel gas.

[0114] In this way, the pressure between the second circulation control valve 31 and the first circulation control valve 8 reaches the predetermined charging pressure, and the pressure between the supply pressure control valve 3 and the second circulation control valve 31 reaches a level greater than the predetermined charging pressure.

[0115] Next, in Step S58, the control unit 21 starts the supply from Step S57, and determines whether or not the pressure is greater than the predetermined charging pressure based on sensor signals from the second pressure sensor 7. When the control unit 21 determines that the pressure has reached a level greater than the predetermined charging pressure, the process advances to Step S59.

[0116] Next, in Step S59, the control unit begins extracting power output generated by the fuel cell stack 1. Here, the control unit 21 controls the supply of the power output obtained from the fuel cell stack 1 to a battery or load (not shown).

[0117] Next, in Step S60, the control unit 21 controls the fifth actuator 33 to open the second circulation control valve 31 and

supplies fuel gas at the power extraction pressure. At the same time, it controls the air supplying device 12 and the discharge pressure control valve 13 to control the oxidant gas pressure so that it changes with the pressure of the fuel gas supplied to the fuel cell stack 1. Here, the control unit 21 controls the supply pressure control valve 3 so that fuel gas is supplied in response to the power extracted from the fuel cell stack 1.

[0118] Next, in Step S61, the control unit 21 inputs sensor signals from the pressure sensor connected to the fuel cell stack 1, and determines whether or not the power output value inputted from the fuel cell stack 1 is less than the predetermined warning lower limit voltage. When the control unit 21 determines that the output voltage is less than the warning lower limit voltage, a normal power generation reaction is not occurring in the fuel cell stack 1 and the process moves to Step S62. When the control unit 21 determines that the voltage output is not less than the warning lower limit voltage, a normal power generation reaction is occurring in the fuel cell stack 1 and the process advances to Step S63.

[0119] In Step S62, a normal power generating reaction is not occurring in the fuel cell stack 1, and the control unit 21 stops the extraction of power output from the fuel cell stack 1. The process then returns to Step S51.

[0120] In Step S63, the control unit 21 determines whether a predetermined amount of time has elapsed since the start of power output extraction from the fuel cell stack 1 in Step S59. When the

control unit 21 determines that the predetermined amount of time has elapsed, the process advances to Step S64. If it determines that the predetermined amount of time has not elapsed, the process returns to Step S61. If, in this way, the control unit 21 determines that the power output value is greater than the warning lower limit voltage when the predetermined amount of time has elapsed since the start of power output extraction in Step S59, the process advances to Step S64.

[0121] In Step S64, the control unit 21 controls the second actuator 9 to open the first circulation control valve 8.

[0122] Next, in Step S65, the control unit 21 after the first circulation control valve 8 has been opened determines whether or not the power output value obtained from the fuel cell stack 1 is less than the predetermined warning lower limit voltage in the same manner as Step S61. If it is less, the process returns to Step S62. If it is not less, the process advances to Step S66 and the fuel cell stack 1 operates normally.

[0123] In a fuel cell system performing this process, power extraction begins from the fuel cell stack 1 when the fuel gas pressure between the supply pressure control valve 3 and the second circulation control valve 31 is greater than the fuel gas pressure between the second circulation control valve 31 and the first circulation control valve 8. Because the opening of the second circulation control valve 31 and the first circulation control valve 8 occur at different predetermined times, the fuel gas can be supplied

at a high flow rate from downstream of the second circulation control valve 31 towards the fuel cell stack 1.

[0124] Thus, this fuel cell system has a faster fuel gas flow rate than the fuel cell system in Figure 1 at the ejector nozzle which discharges fuel gas from the ejector pump 4 into the fuel cell stack 1 when power output extraction begins. This can make the pumping effect of the ejector pump 4 even more efficient and can further stabilize the power output at startup.

[0125] [Startup Control Setting Process]

The fuel cell system described above can perform the startup control setting process in Figure 10 before Step S1 in Figure 9. The control unit 21 begins the startup control setting process at Step S71 based on a command from the outside to start generating power in the fuel cell stack 1.

[0126] First, in Step S71 and Step S72 of Figure 10, the same process as Step S21 and Step S22 described above is performed. This identifies the temperature of the fuel cell stack 1, and the output correction map is referenced to calculate the extractable power output value.

[0127] Next, in Step S73, the control unit 21 uses the extractable power output obtained in Step S72 to calculate the predetermined chargeable pressure used as a reference in Step S56, the pressure greater than the predetermined chargeable pressure used as a reference in Step S58, the pressure at power extraction supplied by the supply pressure control valve 3 at the start of power extraction

in Step S60, and the predetermined amount of time determined by Step S63 from the line capacity of the fuel gas circulation line L2 and the performance of the ejector pump 4. This process begins at Step S51 in Figure 9. Here, the control unit 21 calculates the predetermined amount of time determined in Step S63 to determine the drive timing for the first circulation control valve 8 in Step S64.

[0128] In a fuel cell system performing this startup control setting process, the extractable power output at startup is calculated based on the temperature of the fuel cell stack 1 at startup, and the predetermined charging pressure, the pressure greater than the predetermined charging pressure, the pressure at power extraction in Step S60, and the drive timing for the circulation control valve 8 in Step S64 are changed based on the extractable power output.

[0129] As a result, the optimum power output can be stably obtained at startup in the same manner as the fuel cell system in Figure 1 based on the temperature conditions of the fuel cell stack 1 regardless of the heater or cooler of the fuel cell. Also, the power output can be extracted more quickly and more stably than the fuel cell system in Figure 1.

[0130] [System Restart Control Process]

Figure 11 is a flowchart showing the processing steps performed by the control unit 21 in the fuel cell system of Figure 8 when the system restart control process is performed.

[0131] In Figure 11, the control unit 21 performs Step S81 through Step S87 in the same manner as the process in Step S31 through Step S37 explained above and then advances to Step S88.

[0132] In Step S88, the control unit 21 reads the output versus pressure map stored in the memory showing the relationship between the power output extractable from the fuel cell stack 1 and the residual charging pressure. In this way, the control unit 21 identifies the power output for the residual charging pressure detected in Step S87. Next, the control unit 21 corrects the identified power output based on the temperature detected in Step S87. The predetermined charging pressure, the pressure greater than the predetermined charging pressure, and the driving timing for opening the first circulation control valve 8 are then corrected in order to obtain corrected output power.

[0133] Thus, the control unit 21 performing this system restart control process is able to obtain the same effect as the fuel cell system in Figure 1 and to extract power output more quickly and more stably than the fuel cell system in Figure 1 even after power extraction from the fuel cell stack 1 has been stopped in Step S62.

[0134] [Circulation Flow Rate Control Process During Normal Operation]

Figure 12 shows the processing steps performed by the control unit 21 in the fuel cell system shown in Figure 8 to control the circulation flow rate during normal operation after startup.

[0135] When the fuel cell stack 1 is operating normally, the control unit 21 in Step S91 determines whether or not the purging

operation is necessary when the first circulation control valve 8 is open in the fuel gas circulation line L2. Here, the timing of the purging operation differs from that of the system. If moisture from the fuel gas condenses and collects in the fuel gas circulation line L2 and the gas line for the fuel cell stack 1 becomes clogged with water, or if a trace amount of nitrogen passing from the cathode 1b accumulates and the operating efficiency of the fuel cell stack 1 declines, each problem can be eliminated in a predetermined time frame. If the control unit 21 determines that a purge operation is required, the process moves to Step S92.

[0136] In Step S92, the control unit 21 controls the fifth actuator 33 to narrow the opening of the second circulation control valve 31, and controls the supply pressure control valve 3 to increase the fuel gas supply pressure to the ejector pump 4. Here, the control unit 21 controls the second circulation control valve 31 and the supply pressure control valve 3 so that the flow rate and pressure of the fuel gas supplied to the fuel cell stack 1 does not change. This increases the supply pressure to the ejector pump 4 and increases the flow rate in the ejector nozzle.

[0137] Next, in Step S93, the control unit 21 controls the second actuator 9 to fully open the first circulation control valve 8. It then starts the internal timer and controls the fourth actuator 16 to open the release valve 15 for a predetermined period of time only. This increases the fuel gas flow rate inside the fuel cell stack 1 and the fuel gas circulation line L2 and performs the purging operation.

[0138] Next, in Step S94, the control unit 21 determines from the pressure sensor (not shown) whether or not the cell unit output voltage from the fuel cell stack 1 is lower than the lower limit voltage. If the control unit 21 has determined that at least one cell unit output voltage is lower than the lower limit voltage, the fuel cell stack 1 is operating abnormally and extraction of power from the fuel cell stack 1 is stopped. If the control unit 21 determines that the cell unit output voltage is not lower than the lower limit voltage, the fuel cell stack 1 is generating power normally and the process advances to Step S95.

[0139] In Step S95, the control unit 21 determines whether or not a predetermined amount of time has elapsed on the started timer. If the predetermined amount of time has elapsed, the process returns to Step S91.

[0140] In the fuel cell system shown in Figure 8 performing this process, the flow rate and pressure of the fuel gas supplied to the fuel cell stack 1 does not change. The opening in the second circulation control valve 31 is narrowed, the flow rate is increased in the ejector nozzle, and the condensed moisture and nitrogen gas inside the fuel gas circulation line L2 are readily discharged. The circulatory flow from the first circulation control valve 8 to the release valve 15 returns to the normal direction as soon as the purging operation has been completed (i.e., after the release valve 15 has been closed). Because the pressure inside the fuel gas circulation line L2 is increased immediately before the purging operation, the

condensed moisture and nitrogen gas inside the fuel gas circulation line L2 are even more readily discharged.

[0141] The embodiment described above is an example of the present invention. Therefore, the present invention is by no means limited to this embodiment. Variations other than this embodiment can certainly be devised within the technical scope of the present invention.

[Brief Explanation of the Figures]

[Figure 1] A block diagram of the first configuration example of the fuel cell system of the present invention.

[Figure 2] A flowchart showing the processing steps performed by the control unit in the fuel cell system of the present invention when the start control process is performed.

[Figure 3] (a) is a graph used to explain the change in fuel cell voltage when the fuel cell stack is started up and (b) is a graph used to explain the change in the fuel gas circulation flow rate inside the fuel gas circulation line when the fuel cell stack is started up.

[Figure 4] A flowchart showing the processing steps performed by the control unit in the fuel cell system of the present invention when the start control setting process is performed.

[Figure 5] A graph used to explain the output correction map showing the relationship between the load percentage of the fuel cell stack and the extractable power output changed by the temperature of the fuel cell stack as referenced during the start control setting process.

[Figure 6] A flowchart showing the processing steps performed by the control unit in the fuel cell system of the present invention, when the system restart control process is performed.

[Figure 7] A flowchart showing the processing steps performed by the control unit 21 in the fuel cell system of the present invention when the circulation flow rate control process is performed during normal operations other than startup operations.

[Figure 8] A block diagram of the first configuration example of the fuel cell system of the present invention.

[Figure 9] A flowchart showing the processing steps performed by the control unit in the second configuration example of the fuel cell system when the start control process is performed.

[Figure 10] A flowchart showing the processing steps performed by the control unit in the second configuration example of the fuel cell system when the start control setting process is performed.

[Figure 11] A flowchart showing the processing steps performed by the control unit in the second configuration example of the fuel cell system when the system restart control process is performed.

[Figure 12] A flowchart showing the processing steps performed by the control unit in the second configuration example of the fuel cell system when the circulation flow rate control process is performed during normal operations.

[Figure 13] A block diagram of a configuration of a fuel cell system of the prior art.

[Explanation of the Reference Numerals]

1 Fuel Cell Stack

2 Fuel Gas Supplying Device

3 Supply Pressure Control Valve

4 Ejector Pump

5 First Actuator

6 First Pressure Sensor

7 Second Pressure Sensor

8 Circulation Control Valve (First Circulation Control Valve)

9 Second Actuator

10 Third Pressure Sensor

11 Fourth Pressure Sensor

12 Air Supplying Device

13 Discharge Pressure Control Valve

14 Third Actuator

15 Release Valve

16 Fourth Actuator

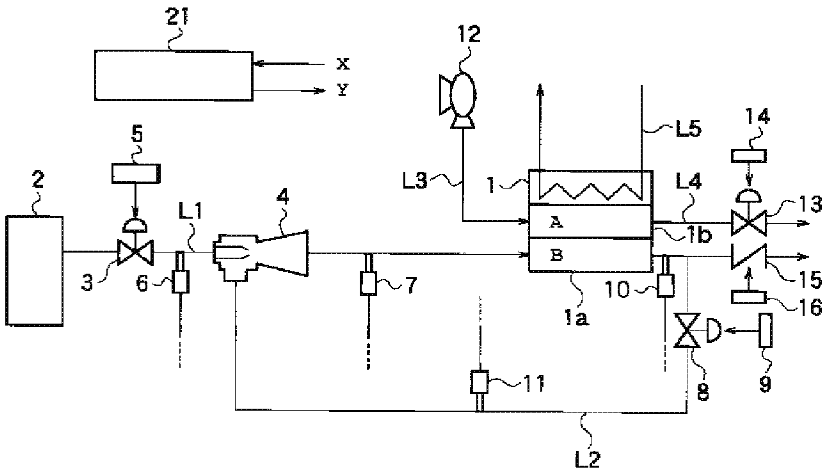
21 Control Unit

31 Second Circulation Control Valve

32 Fifth Pressure Sensor

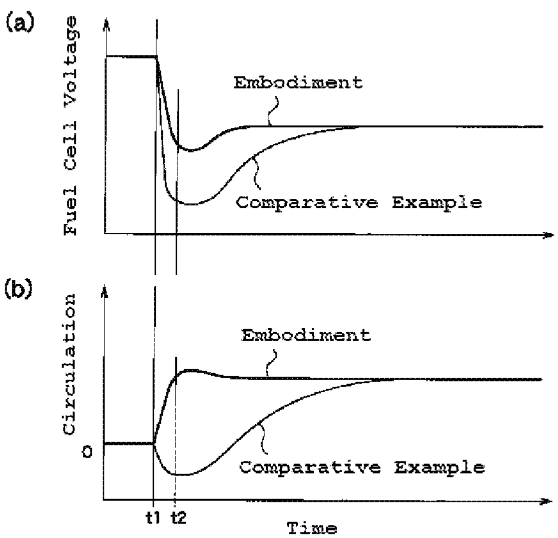
33 Fifth Actuator

[Figure 1]

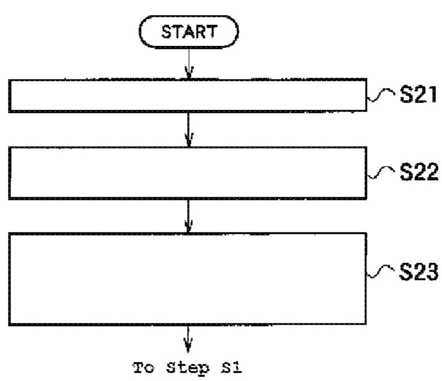


Key:
21 ... Control Unit
X ... Sensor Signal
Y ... Control Signal
A ... Cathode
B ... Anode

[Figure 3]

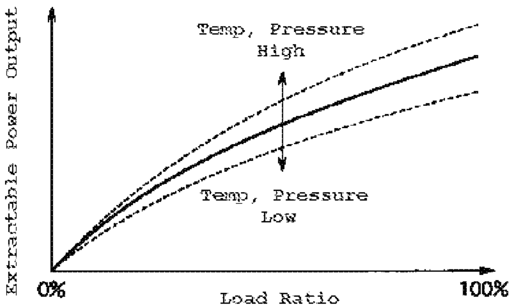


[Figure 4]

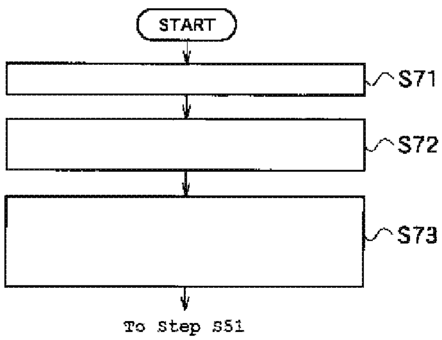


Key:
S21 ... Output Temperature From Fuel Cell Stack Temperature Sensor
S22 ... Calculate Extractable Power Output From Temperature Using Output Correction Map
S23 ... Calculate Fuel Gas Charging Pressure and Pressure Increase at Start of Output From Extractable Output, Calculate Supply Gas Adjustment Valve Opening Time From Conduit Volume and Ejector Performance, Correct These Values Based on Temperature

[Figure 5]

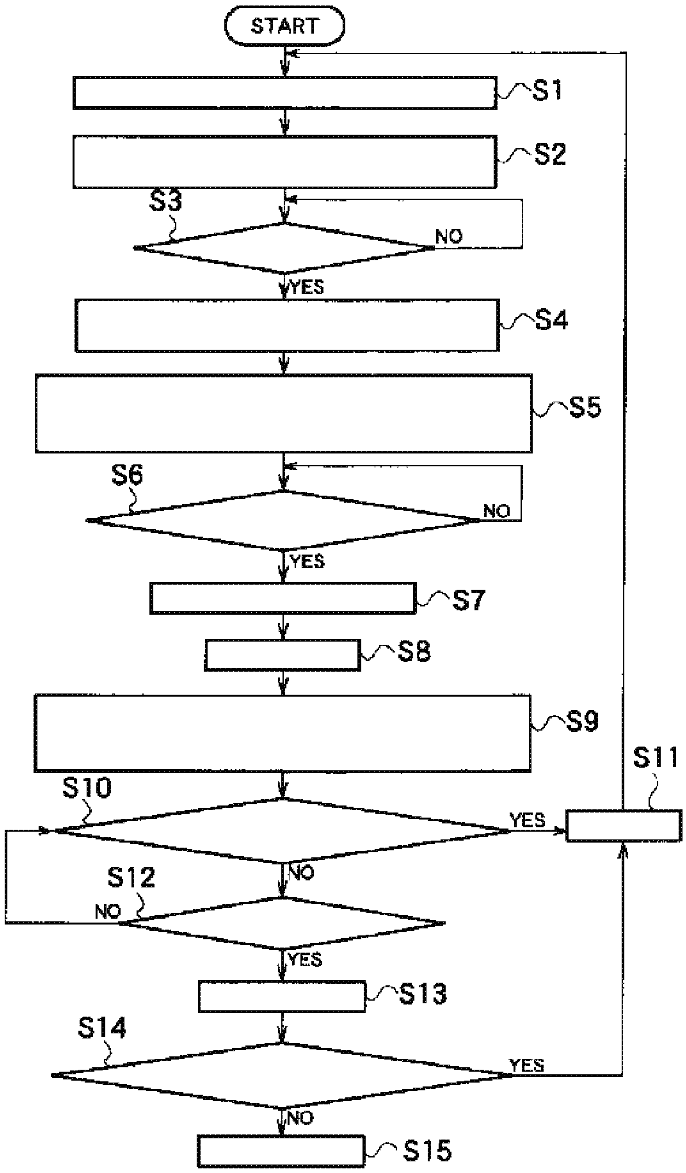


[Figure 10]



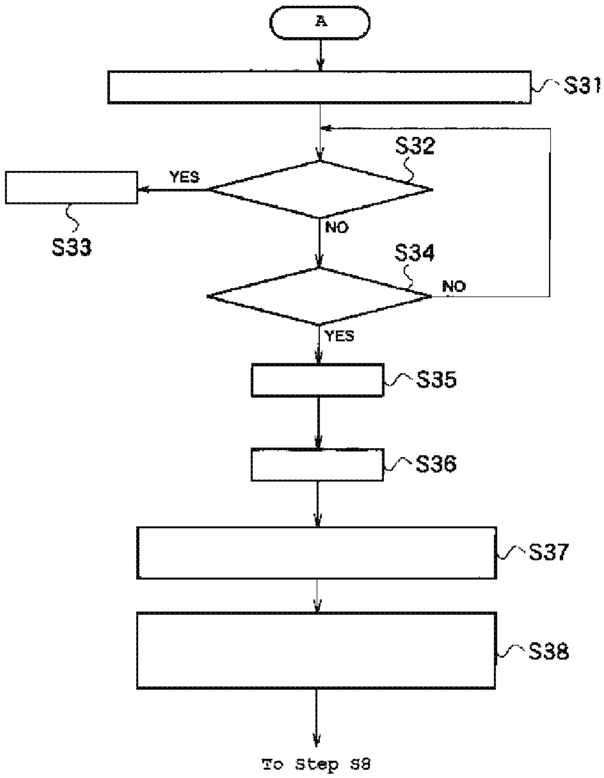
Key:
S71 ... Output Temperature From Fuel Cell Stack Temperature Sensor
S72 ... Calculate Extractable Power Output From Temperature Using Output Correction Map
S73 ... Calculate Fuel Gas Charging Pressure and Pressure Increase at Start of Output From Extractable Output, Calculate First Circulation Control Value Opening Time From Conduit Volume and Ejector Performance, Correct These Values Based on Temperature

[Figure 2]



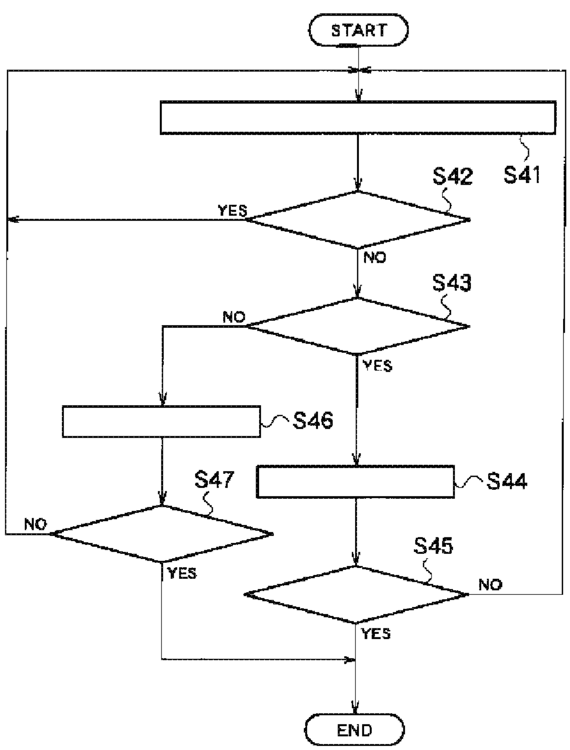
Key:
S1 ... Open Release Valve and Open Circulation Control Valve
S2 ... Supply Fuel Gas and Air From Fuel Gas and Air Supplying Devices, Purge Line
S3 ... Predetermined Time Elapsed?
S4 ... Stop Supply of Gas and Close Release Valve and Circulation Control Valve
S5 ... Supply Fuel Gas at Predetermined Charging Pressure Using Supply Pressure Control Valve, and Simultaneously Supply Air at Same Pressure Using Discharge Pressure Control Valve
S6 ... Predetermined Charging Pressure Reached?
S7 ... Maintain Predetermined Charging Pressure
S8 ... Start Output
S9 ... Open Supply Pressure Control Valve to Predetermined Setting, and Simultaneously Use Discharge Pressure Valve For Air to Bring Air Supply Pressure Into Compliance With Fuel Gas Supply Pressure
S10 ... Below Warning Lower Limit Voltage?
S11 ... Stop Output
S12 ... Predetermined Time Elapsed?
S13 ... Open Circulation Control Valve
S14 ... Below Warning Lower Limit Voltage?
S15 ... Normal Operation

[Figure 6]



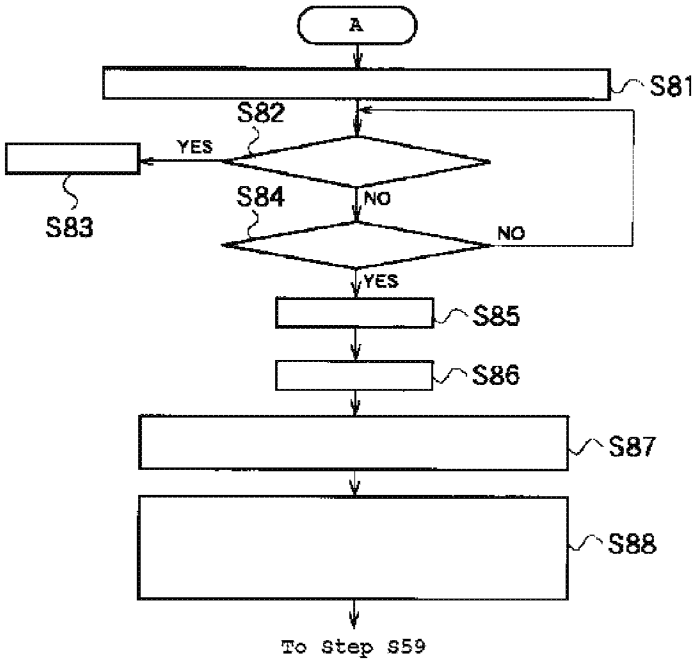
Key:
A ... Stop Output
S31 ... Charge Fuel Cell With Fuel Gas and Oxidant Gas at Predetermined Pressure
S32 ... Output Request?
S33 ... To Normal Operation
S34 ... IGN OFF?
S35 ... Stop System
S36 ... Restart System
S37 ... Detect Temperature From Temperature Sensor, Detect Remaining Charging Pressure From Pressure Sensor
S38 ... Calculate Extractable Output at Remaining Pressure Using Output/Pressure Map, Correct Extractable Output From Temperature

[Figure 7]



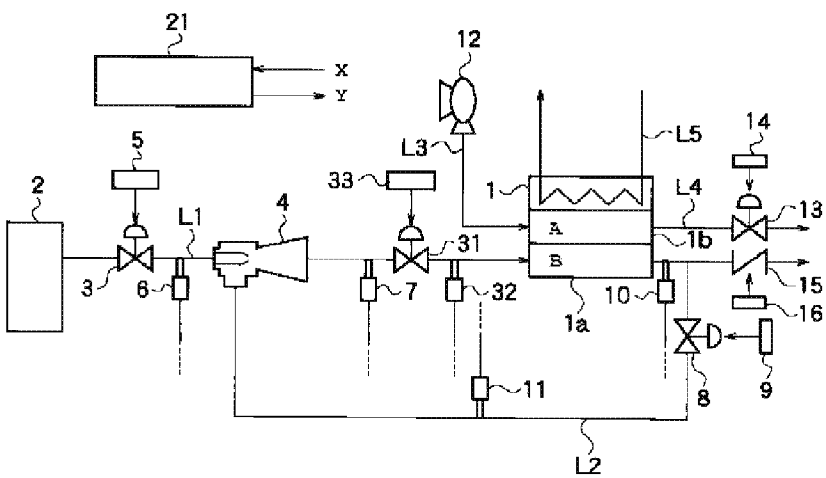
Key:
S41 ... Calculate Optimum Circulation Flow Rate From Current Fuel Cell State
S42 ... Circulation Flow Rate Value Optimized?
S43 ... Circulation Flow Rate > Optimum Rate?
S44 ... Open Circulation Control Valve More
S45 ... Close Circulation Control Valve More
S46 ... End Output?
S47 ... End Output?

[Figure 11]



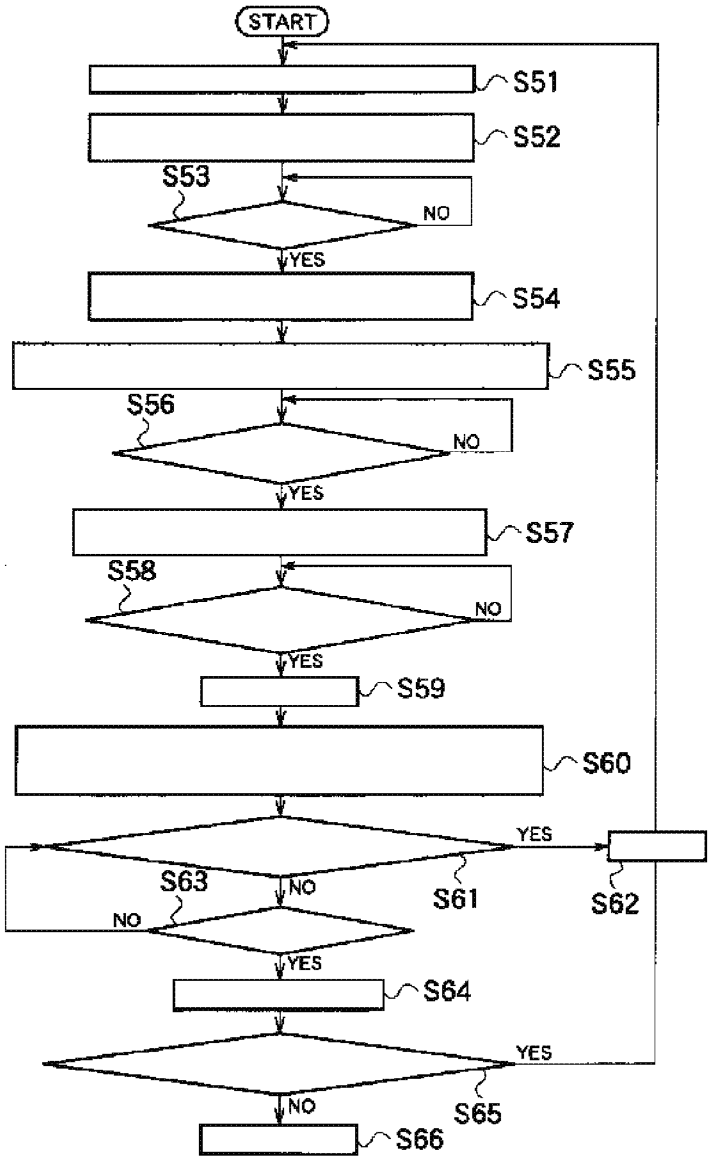
Key:
A ... Stop Output
S81 ... Charge Fuel Cell With Fuel Gas and Oxidant Gas at Predetermined Pressure
S82 ... Output Request?
S83 ... To Normal Operation
S84 ... IGN OFF?
S85 ... Stop System
S86 ... Restart System
S87 ... Detect Temperature From Temperature Sensor, Detect Remaining Charging Pressure From Pressure Sensor
S88 ... Calculate Extractable Output at Remaining Pressure Using Output/Pressure Map, Correct Extractable Output, Supply Pressure Prior to Start of Output, and First Circulation Valve Opening Time From Temperature

[Figure 8]



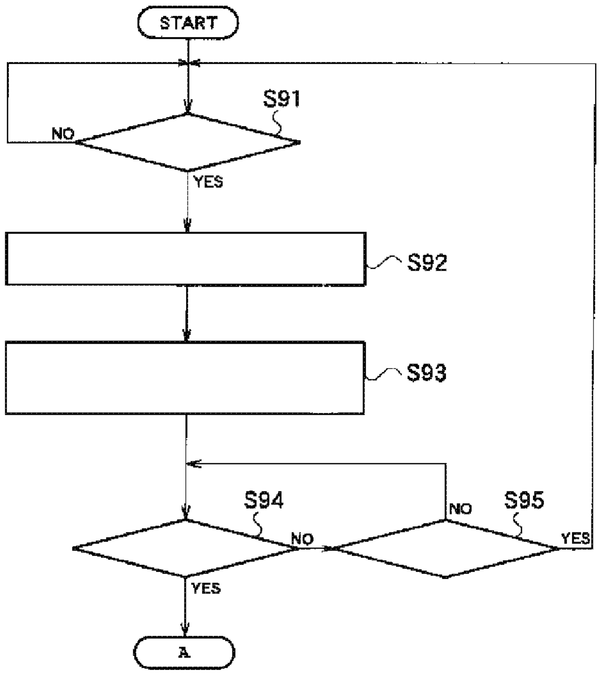
Key:
21 ... Control Unit
X ... Sensor Signal
Y ... Control Signal
A ... Cathode
B ... Anode

[Figure 9]



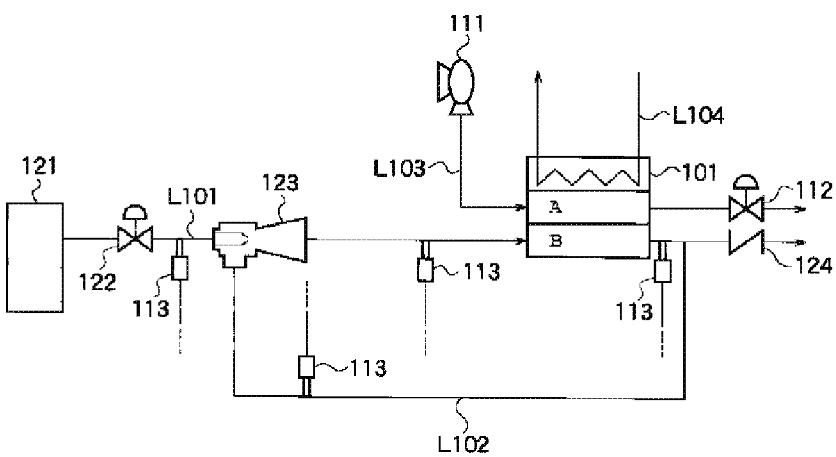
Key:
S51 ... Open Release Valve and First and Second Open Circulation Control Valves
S52 ... Supply Fuel Gas and Air From Fuel Gas and Air Supplying Devices, Purge Line
S53 ... Predetermined Time Elapsed?
S54 ... Stop Supply of Gas and Close Release Valve and First Circulation Control Valve
S55 ... Supply Fuel Gas at Predetermined Pressure Using Supply Pressure Control Valve, and Simultaneously Supply Air at Same Pressure Using Discharge Pressure Control Valve
S56 ... Predetermined Charging Pressure Reached?
S57 ... Close Second Circulation Control Valve and Supply Pressure Higher Than Charging Pressure Using Supply Pressure Control Valve
S58 ... Pressure Higher Than Predetermined Charging Pressure Reached
S59 ... Start Output
S60 ... Open Second Circulation Control Valve, and Simultaneously Use Discharge Pressure Valve For Air to Bring Air Supply Pressure Into Compliance With Fuel Gas Supply Pressure (Supply Pressure Control Valve Adjusts Pressure to Conform to Extractable Output)
S61 ... Below Warning Lower Limit Voltage?
S62 ... Stop Output
S63 ... Predetermined Time Elapsed?
S64 ... Open Circulation Control Valve
S65 ... Below Warning Lower Limit Voltage?
S66 ... Normal Operation

[Figure 12]



Key:
S91 ... Circulation Line Purge Required?
S92 ... Control Second Circulation Control Valve in Closing Direction and Increase Supply Pressure For Ejector
S93 ... Fully Open First Circulation Control Valve and Open Release Valve Near Fuel Cell Outlet Based on Predetermined Timer Setting
S94 ... Cell Voltage < Lower Limit?
S95 ... End Timer?

[Figure 13]



Key:
A ... Cathode
B ... Anode